5. Geologic Assessment Overview

Although gravitational failure of sediment and rock is a natural process, knowing where landslides and rockfalls might occur or what might accelerate or reactivate them can help minimize their impact. The main product of the assessment is a digital map atlas. This atlas describes the geologic context and is the final part of a three-phase landslide inventory for Hennepin County Emergency Management.

After recent precipitation-induced landslides in the region, Hennepin County Emergency Management initially funded the first assessment phase — an historical inventory of failures that was based primarily on newspaper reports and historical records. A year-long pilot project to create the historical inventory of slides involved staff at the Minnesota Department of Natural Resources (MnDNR); two students and faculty at University of Minnesota, Department of Earth Sciences; the National Weather Service; the Federal Emergency Management Agency (FEMA); and Hennepin County Emergency Management *(Jennings et al., 2016)*.

The second phase, completed by two of the same researchers *(Jennings and Kurak, 2018)*, used high-resolution elevation models prepared by Hennepin County to locate slides of unknown age and categorize them. In addition to Hennepin County Emergency Management, this phase was also supported by the Hennepin County Regional Rail Authority (HCRRA). The historical landslide locations were plotted on a LIDAR-derived hillshade digital elevation model (DEM) to learn the expression of landslides. Three main types of slope movement were identified in Hennepin County, two of which can be seen on the hillshade DEM.

1) Rotational landslides — downslope movement of sediment on a curvilinear surface rupture resulting in a headscarp and lobate deposit. Deposits can be blocky and sometimes involve liquefaction. Large rotational landslides estimated to be more than 4.5 meters (15 feet) deep were separated from smaller failures in the map.
2) Small debris flows — typically a mixture of water, sediment, rock and debris that has become a slurry and moves downslope, commonly with some speed. This category includes areas of multiple small slides, dry failure of sand and colluvial or alluvial fans.
3) Topple or falls of rock — defined by rapid, nearly vertical movement of masses of bedrock or boulders are known to occur, but are not distinguishable on the DEM.

The second assessment phase identified 203 scarps, 134 of which had clear, lobate deposits. There were 1,146 small slide areas scattered on steep slopes in glacial sediment, primarily till and modified till. These occurred along shorelines and areas of focused overland flow like ravines. In these settings, ongoing erosional processes continue to steepen slopes, priming them for failure. Human alteration to these slopes that mimic erosion, steepen them, or saturate them can also cause failure, e.g., focused discharge, cutting away at the toe, or infiltration of water from the top.

The third assessment phase was supported by Hennepin County Emergency Management and by three watershed districts in Hennepin County: Lower Minnesota (LMRWD); Mississippi (MWMO); and Riley Purgatory Bluff Creek (RPBCWD) and benefited from the assistance of the Minnesota River National Wildlife Refuge. During this phase, a combination of field investigation by Freshwater geologists and compilation of geologic data provided by the Minnesota Geological Survey (MGS) refined our understanding of the geologic units involved in four main types of slides present in the county:

1) bedrock-dominated landslides on near-vertical bluffs
2) deep-seated landslides in glacial sediment
3) shallow landslides in glacial sediment
4) slides along the widening slopes of rivers

The bedrock-dominated slides were not observable on the high resolution elevation model because they were located on near-vertical bedrock-dominated slopes along the Mississippi River gorge. These were field-checked and their occurrence compared to spring-discharge points and the bedrock units involved. Monitoring the bluff or infrastructure on top of the bluff for movement can help anticipate and avoid damage. Providing a fall zone is prudent.

Deep-seated slides along the Minnesota River valley involved glacial units that are not well exposed and required the use of the logs of borings and cross sections created by the MGS for the revised Geologic Atlas of Hennepin County *(Steenberg et al., 2018)*. The largest failures in Hennepin County can be found along the Minnesota River valley, but most predate settlement of the area. However, human activity in the area has the potential to reactivate failures. Springs along stratigraphic contacts in the glacial sequence influence the location of failure by steepening slopes and creating sapping hollows. Wise land-use practices based on sound geotechnical site investigation and protecting the slope by careful routing of storm water can reduce the chances of reactivation.

Shallow slides in the interior of the county involve the upper, lower-density layer of the surficial glacial sediment deposits. Textures of soil and parent material involved in shallow slides varied significantly so correlation to a particular soil type is not apparent. Setbacks from slopes and river banks can reduce damages and financial losses. Cooperation between landowners at the top and bottom of the slope is key to maintaining slope integrity.

This atlas presents results of geological investigations into the three types of slides and provides recommendations for approaches to reduce impacts.

The methods and geodatabase created for this project are consistent with a statewide project that is underway and funded by the Legislative and Citizens Commission on Minnesota Resources (*Gran et al., 2016)*.